Calculation of Blackbody Radiation Stripping using Hill-Bryant Method

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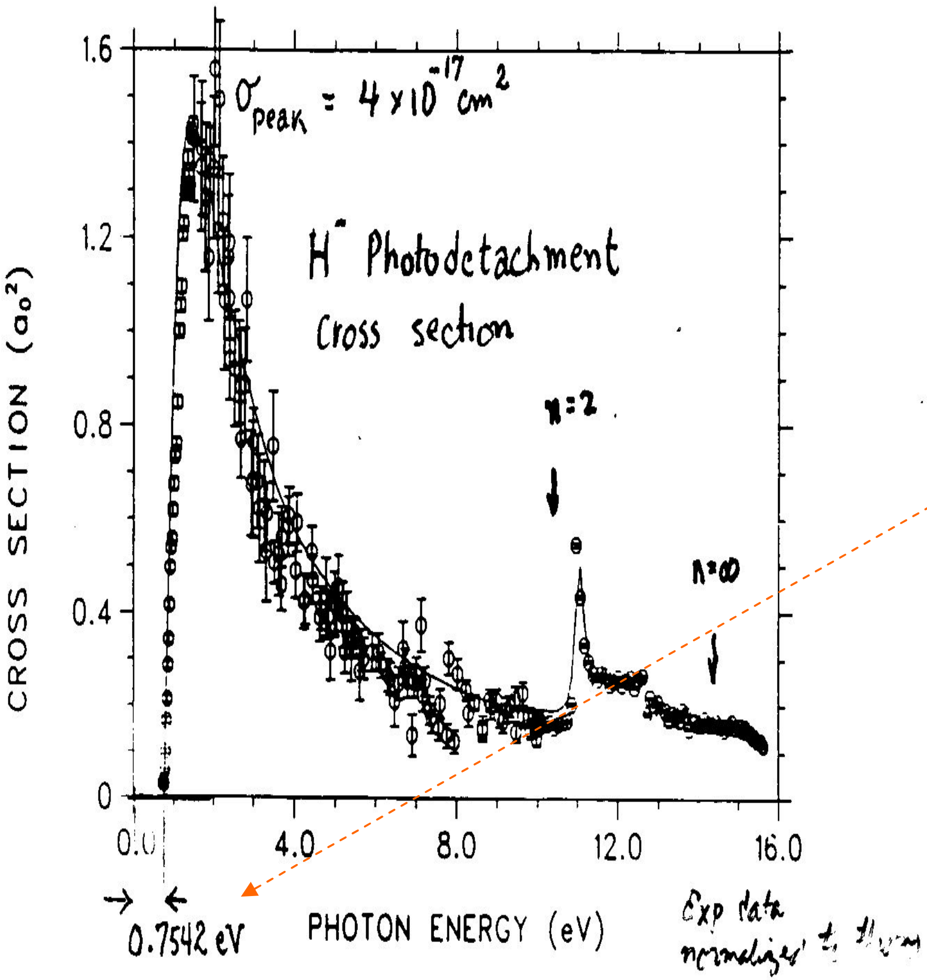
H^- Photo-Detachment Spectrum (I)



- The unit of the x-section is a_0

  For Hydrogen,

  $$a_0 = 0.529 \times 10^{-10}(m)$$

  $$\sigma_{peak} = \sigma_{\max} = 4.2 \times 10^{-21}(m^2)$$

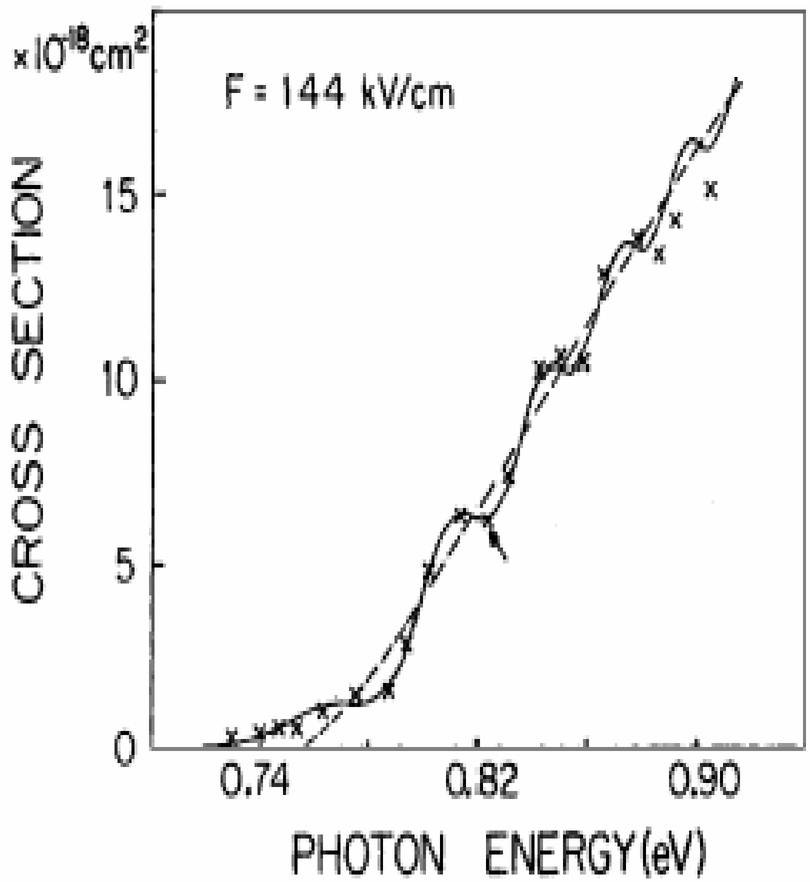
- Threshold, E_0 = 0.7542 (eV)

  (**E**lectron **A**ffinity of Hydrogen)
- As the E_γ increases, the x-section rises to the power of 3/2 first, then, peaks at about 1.5 (eV)
- As the spectrum tails out, the structure persists from around

  10.9 (eV) thru 14.35 (eV)

  (= 13.6 + 0.7542 eV).

H^- Photo-Detachment Spectrum (III)



- Photo-detachment of H^- just above threshold, 0.75 eV (*dashed line*), and in the presence of electric field (*solid line*).

- Photo-detachment sets off below detachment threshold, 0.75 eV, and the field-induced ***ripple-like structure*** appears in the presence of electric field at higher E_γ .

Collision Length Calculation (I)

Collision Length, $L \sim 1/\langle \rho\sigma \rangle$

Differential Number Density of Photons by Bose-Einstein distribution can be approximated to Maxwell-Boltzmann distribution $E_\gamma = |\vec{k}| \sim 1\,(\mathrm{eV})$, $T_{Room} = 1/40\,(eV)$

$$d\rho = \frac{d^3\vec{k}}{(2\pi)^3} \cdot \frac{2}{\exp(|\vec{k}|/T) - 1} \approx 2 \cdot \frac{d^3\vec{k}}{(2\pi)^3} \cdot \exp(-|\vec{k}|/T)$$

$$\frac{1}{L} = \frac{T^2}{2\pi^2\gamma} \cdot \int_0^\infty dE \cdot \sigma(E) \cdot (1 + E/T_h) \cdot \exp(-E/T_h)$$

$$T_h = T_R \cdot \sqrt{\frac{1+\beta}{1-\beta}} \approx 2\gamma T_R$$

relativistic Doppler blue-shifted to T_h, and Doppler-red-shifted effective temperature term is suppressed with given input parameters.

$$\sigma(E) = \frac{8\sigma_{max} E_0^{3/2}(E - E_0)^{3/2}}{E^3}$$

$$\sigma_{max} = 4.2E-21(m^2),\ E_0 = 0.7543(eV)$$

Collision Length Calculation (II)

- As the natural units $(c = \hbar = \kappa_B = 1)$ is used in C. Hill's equation, conversion factor, $(\hbar c)^3$, needs to be added to the pre-factor for numerical calculation.

$$\frac{1}{L} = \frac{T^2}{2\pi^2\gamma} \cdot \int_0^\infty dE \cdot \sigma(E) \cdot (1 + E/T_h) \cdot \exp(-E/T_h)$$

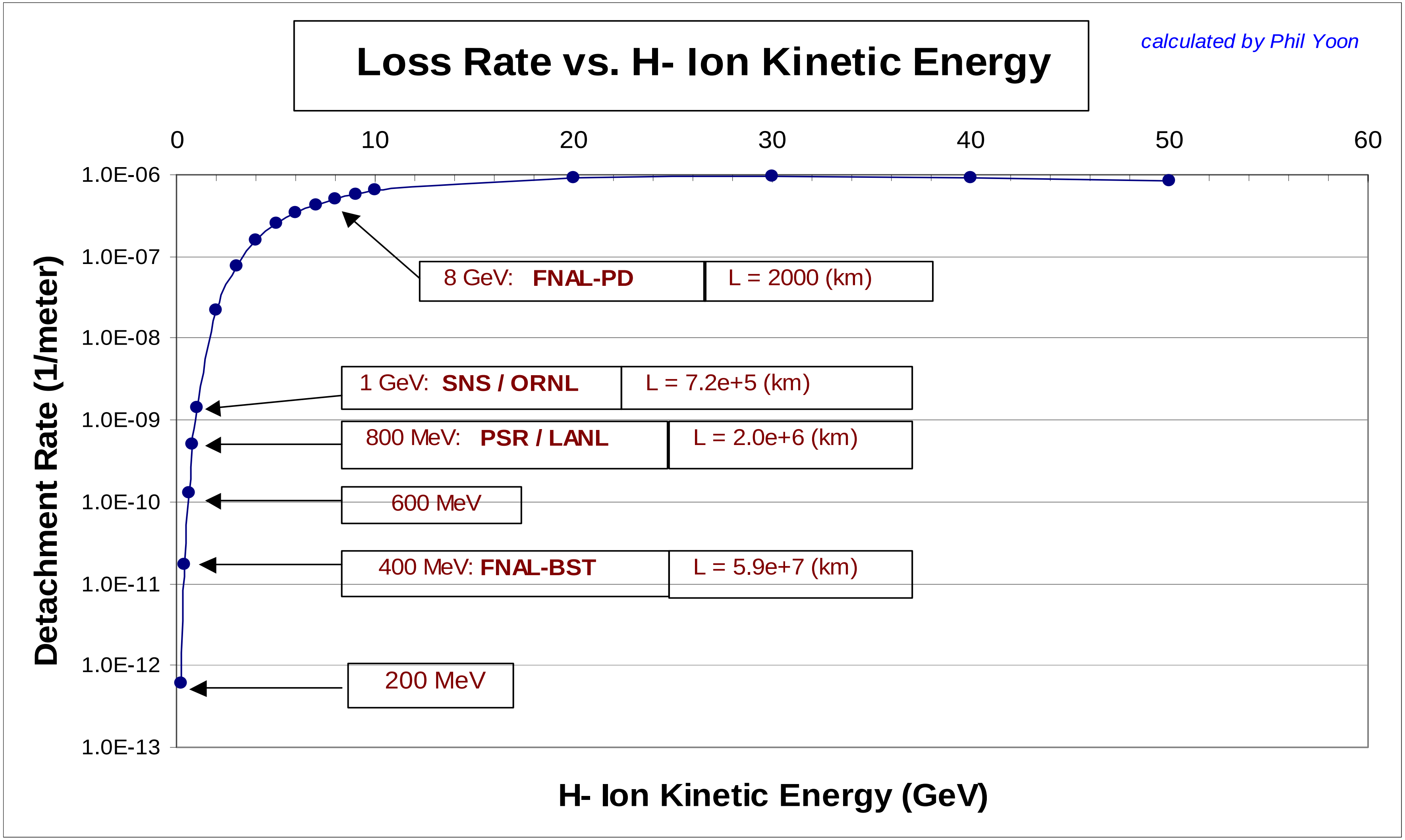
$$= \frac{8T^2\sigma_{max} \cdot E_0}{2\pi^2(\gamma\beta)(\hbar c)^3} \int_1^\infty d\varepsilon \frac{(\varepsilon - 1)^{3/2}}{\varepsilon^3} (1 + \left(E_0/T_h\right)\varepsilon) \cdot \exp(-(E_0/T_h)\varepsilon)$$

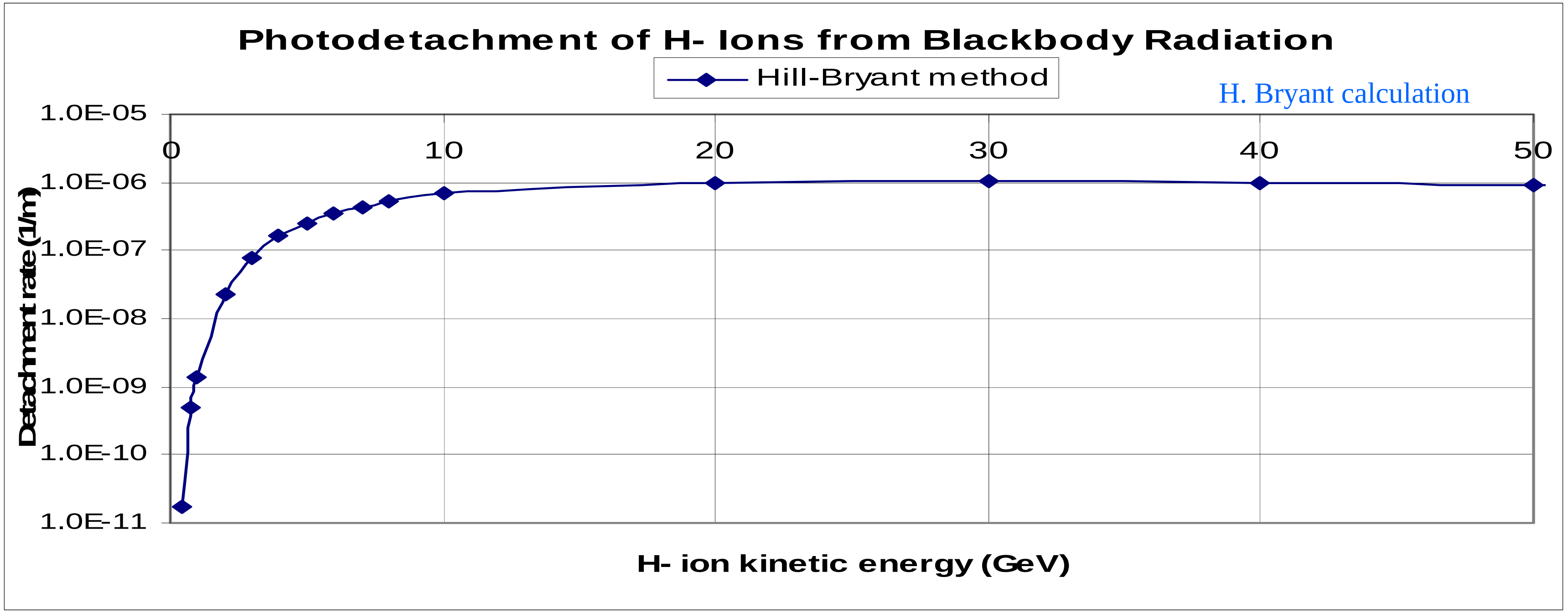
$$(\varepsilon = E/E_0)$$

$$\therefore L \approx 2000(km)$$

@ E = 8 (GeV), T_{room} = 300 (°K)

Detachment Rate vs. H$^-$ Ion Kinetic Energy (I)




Photodetachment of H- Ions from Blackbody Radiation
Hill-Bryant method
H. Bryant calculation
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
1.0E-11
0
10
20
30
40
50
Detachment rate (1/m)
H- ion kinetic energy (GeV)

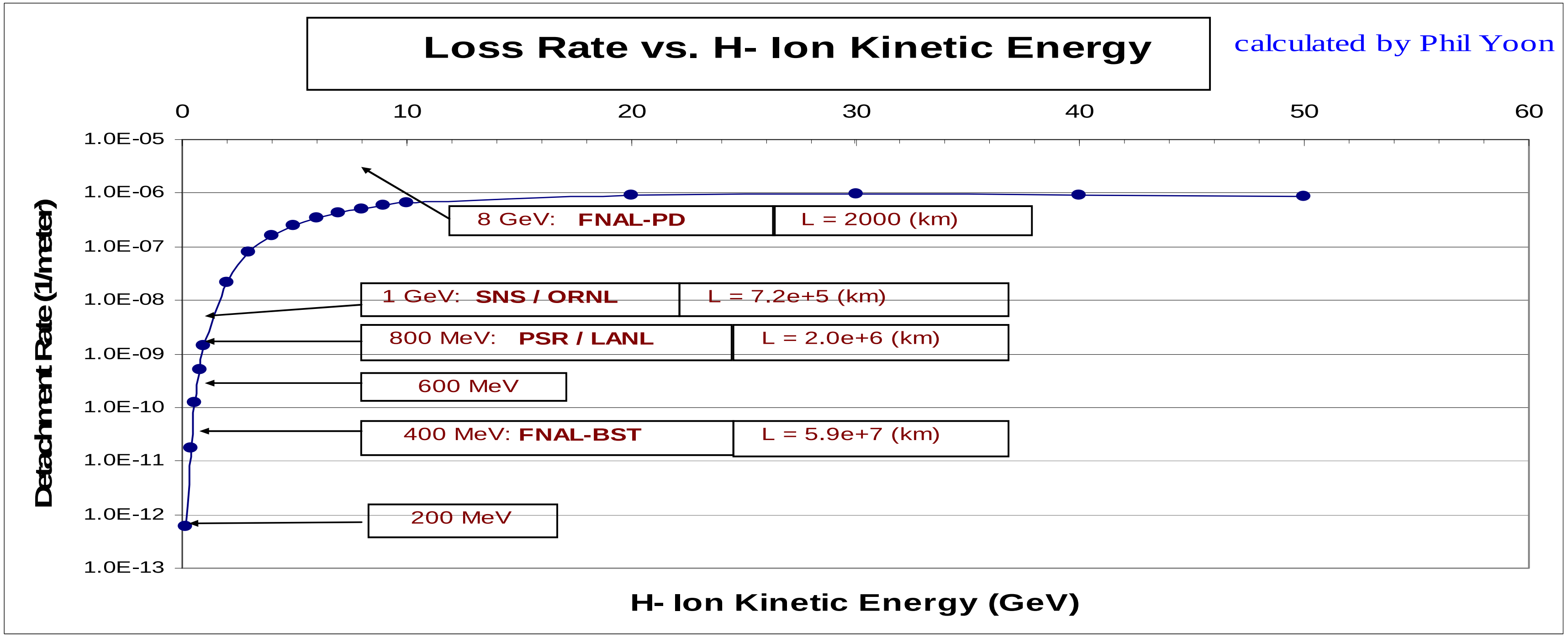
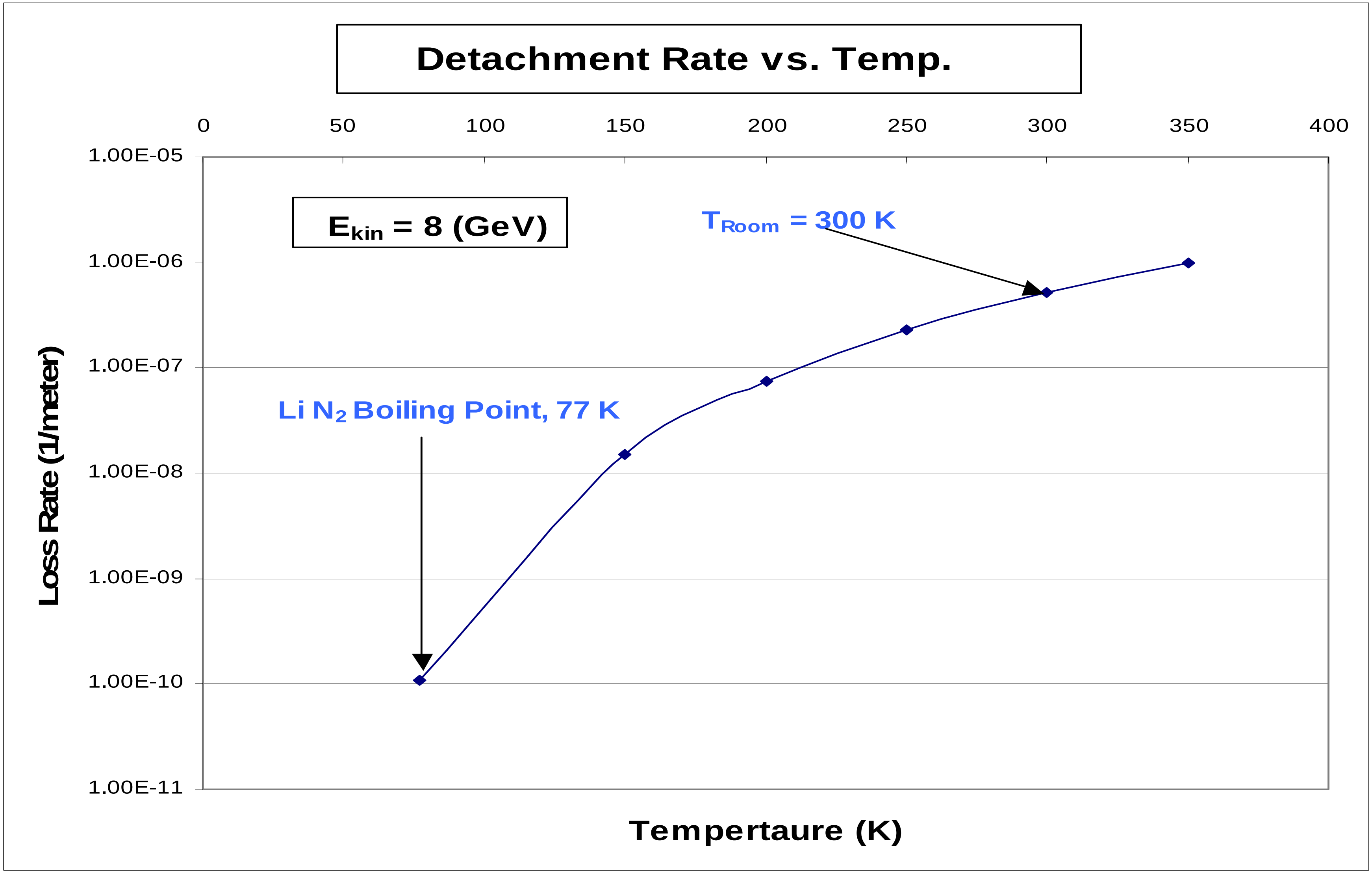

Loss Rate vs. H- Ion Kinetic Energy
calculated by Phil Yoon
0
10
20
30
40
50
60
1.0E-05
1.0E-06
1.0E-07
1.0E-08
1.0E-09
1.0E-10
1.0E-11
1.0E-12
1.0E-13
8 GeV: FNAL-PD
L = 2000 (km)
1 GeV: SNS / ORNL
L = 7.2e+5 (km)
800 MeV: PSR / LANL
L = 2.0e+6 (km)
600 MeV
400 MeV: FNAL-BST
L = 5.9e+7 (km)
200 MeV
Detachment Rate (1/meter)
H- Ion Kinetic Energy (GeV)

Photo-Detachment Rate vs. Temperature



Concluding Remarks

- With the Hill-Bryant method, two different numerical calculations (Excel and Mathematica) agree well that the loss rate is about 5.0e-7 / meter at 8 GeV.

- The higher H^- ion beam energy is, more likely to be stripped by thermal photons.

- When beam energy jumps to 8 GeV from 0.8 GeV, stripping by blackbody radiation and loss rate increase by 3 order of magnitude.

- As the temperature rises from Li Ni_2 boiling point to room temp. detachment rate increases by three order of magnitude.